Laser Depaint Technology for Aerospace Applications

Mr. Gerard Mongelli (*CTC*) (on behalf of)
Mr. Tom Naguy (AFRL/RXSC)
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OVERVIEW

- Problem Statement
- Air Force Laser Depaint Program
- Current Laser Depaint Technologies
- Future Laser Depaint Technologies
- Summary

Problem Statement

- US Air Force operates three Air Logistics Centers for depot maintenance of aircraft
- Coatings removal operations are performed extensively as part of this maintenance
  - Current methods are time consuming processes that create hazardous waste and emissions as well as require large quantities of rinse water

Chemical Stripping

Plastic Media Blasting

Hand Sanding

Air Force Laser Program

AFRL and HQ AFMC identified laser technology as a viable alternative and initiated the AF Laser Program

Program Goal:

Establish and expand the use of laser technology as a viable alternative technology for depot maintenance operations

Benefits:

- ✓ Environmentally Friendly
- ✓ No Damage to Substrate
- ✓ Reduce Flow Time
- ✓ Cost Effective
- ✓ Safety Compliant
- ✓ Increase Facility Capacity

Air Force Laser Program

Phased approach taken to validate and implement laser coating removal technology throughout all areas of maintenance performed by the Air Force

Phase I
Handheld laser coatings

COMPLETED

Phase II
Large area, off-aircraft laser coatings removal applications

COMPLETED

Phase III
Next generation large area, off-aircraft laser coatings removal applications

COMPLETED

Phase IV
Automated full aircraft laser coating removal applications

IN-PROCESS

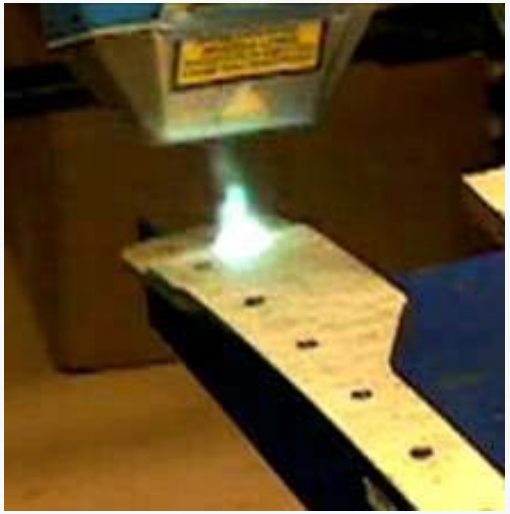
PHASE I
Handheld Laser Coatings Removal Systems

Objective:

- Evaluate ability of hand-held laser systems to supplement existing small-area depainting processes on components and aircraft at depots

Benefits / Impacts:

- Increase production rate
- Replace chemicals and blast media use
  - Reduce hazardous waste generation
  - Reduce hazardous air emissions
  - Reduce storage/handling and worker exposure to hazardous materials



PHASE I
Handheld Laser Coatings Removal Systems (cont.)

- Identified and evaluated commercially available handheld lasers
- Results:
  - Adequate average removal rate for small area/nitpicking operations (≈14 in^2/min)
  - No visual indication of surface damage
  - Measurements confirmed temperature spikes are not high enough to cause damage (<200° F)
  - All clad substrates tested indicated no clad penetration occurred
  - No indication of excessive surface roughness
  - Adhesion properties not adversely affected
  - Fatigue and tensile results comparable to published results from other stripping methods

Cost Benefits Analysis Results

$100K Annual savings, $1.2M Life Cycle Cost Savings, and
2.2 year Return On Investment (ROI)

PHASE I
Handheld Laser Coatings Removal Systems (cont.)

- Laser technology proving to be a viable alternative to present de-painting operations as a supplemental approach
  - Positive results achieved during the laboratory testing
- Results being utilized by other organizations to develop laser depaint capabilities
- Handheld laser technology deployed to DoD
  - U.S. Air Force Depots
    - Oklahoma City Air Logistics Center (OC-ALC)
    - Ogden Air Logistics Center (OO-ALC)
    - Warner-Robins Air Logistics Center (WR-ALC)
  - U.S. Army (Ft. Rucker, AL)
  - U.S. Coast Guard Aviation Logistics Center (Elizabeth City, NC)
- Based upon this successful program Air Force proceeded with robotic laser technology for large surface area applications

Handheld systems implemented and approved for use

PHASE II

Robotic Laser Coating Removal System (RLCRS)

Objective:

- Develop robotic laser coating removal system to replace current chemical coating removal methods used on large aircraft components

Benefits/Impacts:

- Reduce stripping time and replace chemicals and blast media usage
- Potential reductions at OC-ALC include:
  - 13,200 gallons paint stripper
  - 341,260 pounds of solid waste
  - 4003 pounds of VOCs
  - 1,815,000 gallons contaminated waste water
  - $390K savings in annual environmental costs

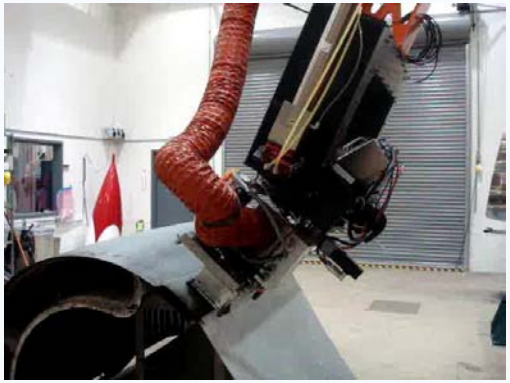
PHASE II
RLCRS (cont.)

- Design and construction of RLCRS was successful
- Material testing confirmed the safe use of RLCRS technology
- System successfully transitioned to OC-ALC
  - Operators from all 3 shifts have been trained / used equipment at OC-ALC
  - Demonstrations have been conducted for E-3, B-1, and KC-135 Engineering Offices
- Approval for production usage has been granted by 1of the 3 major weapon systems processed at OC-ALC
- Based on positive results, Ogden ALC commissioned the design and construction of new RLCRS to replace existing laser system for radome depainting

<u>Cost Benefits Analysis Results</u>
$7.5 M Annual savings and
<1 year Return on Investment (ROI)

PHASE III

Advanced Robotic Laser Coating Removal System (ARLCRS)



Objective:

- Replace Laser Automated De-coating System (LADS) for OO-ALC
- Integrate proven laser technology with a large robotic platform to create automated system for de-painting radomes and other off-aircraft components

Requirements:

- Ability to strip A-10, F-16 and C-130 radomes and off-aircraft parts
- Incorporate commercially available and production proven laser, robot and control components to maximum extent possible
- Integrate contour following to maintain accurate stand-off and focal length
- Perform stripping in +/- x direction

PHASE III
ARCLRS (cont.)

Benefits/Impacts:

- Uses commercially available and production proven laser components
- Able to strip A-10, F-16 and C-130 radomes and other off-aircraft parts
  - Multiple part geometries may be processed due to rail & robot arm design
- Real-time contour following capability – no specific path programming required
- Real-time surface temperature measurements
- Smaller footprint
- Faster strip rates
  - LADS took 4+ hours to strip F-16 radome and ARLCRS takes about 1/2 hour.
- Cost savings of ~$330,000 annually for F-16 radomes
  - Additional savings will be realized as system is used on other large off-aircraft parts

LADS took 4+ hours to strip F-16 radome
ARLCRS (LADS II) takes about ½ hour

PHASE III
ARCLRS (cont.)

VS.

- System successfully transitioned to OO-ALC
  - Currently in production operation de-painting F-16 radomes
- Conducting test and evaluation with other weapons system program offices and engineering authorities for other components
  - Working with C-130, A-10 and F-16 SPOs
  - Future plans to work with F-22 and B-2 SPOs

<u>Cost Savings</u>

$300,000 Annual Savings for F-16 radomes

Increased capacity 80% - now able to process large off-aircraft parts

Future Robotic Technology
Full Aircraft Coating Removal Systems

Objective:

- Design and demonstrate robotic laser coating removal system for multiple aircraft types

Requirements:

- Maximize quality and coverage
- Maximize throughput
- Robust to handle variations in aircraft shape
- Minimize preparation & manpower requirements
- Scalable to multiple robots and aircrafts
- Maintainable by maximizing the use of standard COTS components and modular subsystems
- Design for multi-purpose use
- Low impact infrastructural footprint

Future Robotic Technology
Full Aircraft Coating Removal Systems (cont.)

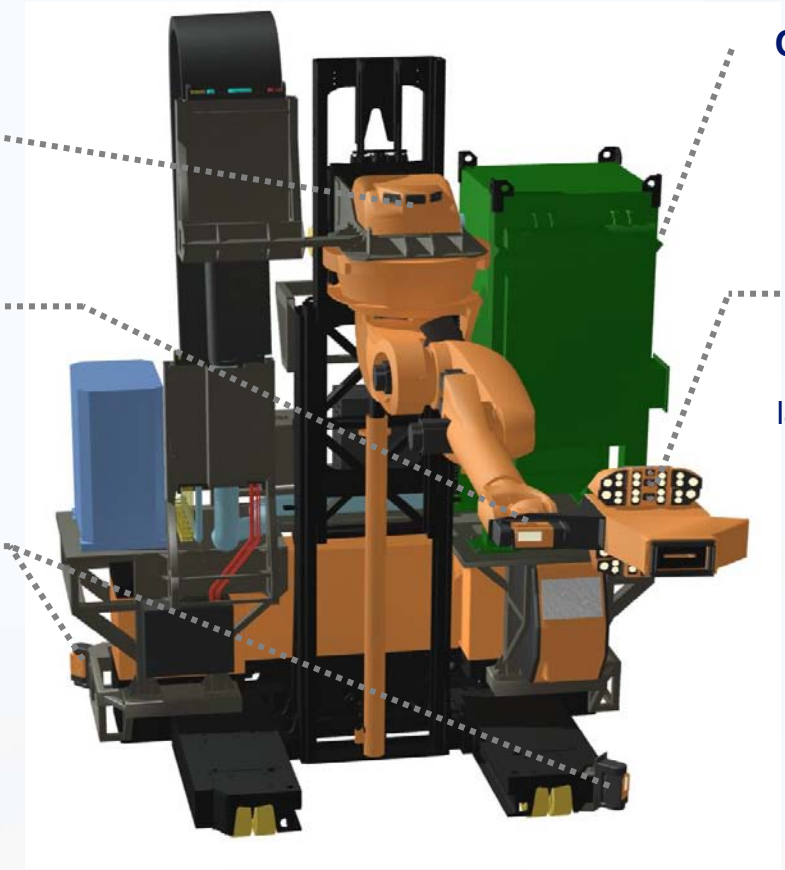
- System will utilize advanced sensors and autonomy providing intelligent robotic motions to achieve optimal processing time and results during coating removal operations
- Surface Classification Software:
  - Online discrimination of paint, primer, and raw surface (i.e. bare metal) using sensed surface properties allowing processing down to primer or bare metal.
- Measured Surface Properties:
  - Color, roughness, spectral reflectance distribution
- Design Approach :
  - Combine line striper and color cameras, LED light sources from multiple directions, and spectral signature of coating removal process
- System will be open for additional sensors to be incorporated for other operations (corrosion detection, etc.)
- 3D aircraft model creation with stored surface properties
- Collaborative robotics:
  - the system dynamically adapts to unforeseen events and hardware failure.
- Supervised Autonomy, wizard base GUI , 3D visualization and virtual masking
- Precise closed-loop robot to airplane positioning & Obstacle detection sensing
- Mobile system able to be swapped out for maintenance

Future Robotic Technology
Full Aircraft Coating Removal Systems (cont.)

Pose Box
- Localizes position of KUKA arm

Arm mounted Laser Scanner
- Creates 3D model of work surfaces

Base mounted Laser Scanners
- Acts as “Virtual Bumper”
- Each scanner has 270 degree sweep



Particle Collection System

Surface Analysis Pod
- Gathers data for laser stripping process

Future Robotic Technology
Full Aircraft Coating Removal Systems (cont.)

- System Advantages
  - COTS vs. Custom: System is designed to use as many COTS components as possible. This approach will ensure low duplication cost, long term maintenance and future upgrade path.
  - Scalability: the system is designed to scale from a small plane to a larger one with minimal to no hardware changes.
  - Redundancy: all the robots are identical and can be used to replace each other
  - Ease of setup: the system can be installed in a new building with minimal infrastructure (only laser and tether installation)
  - Flexibility: because the robot is mounted on a mobile platform, the approach angle can be adjusted in a very flexible way. For example, the robot can be positioned between the two tail fins that are on some airplane.
  - Precise closed-loop robot to airplane positioning: we are not relying on just the encoders in the robot arm for the precise positioning.

PHASE IV
Full Aircraft Coating Removal Systems (cont.)

- Fiber laser now being tested on various substrate/coating combinations to validate compatibility
  - 4 cycles of coating/laser stripping followed by mechanical testing underway
    - **Aluminum Substrate:** Strip Rate, Visual Assessment, Substrate Temperature, Electrical Conductivity, Surface Hardness, Tensile, Smooth and Notched Fatigue, Cross-Section SEM and Micro-hardness
      - Materials testing in progress - ECD 03/11
    - **Graphite-Epoxy Composite:** Strip Rate, Visual Assessment, Substrate Temperature, Visual Damage, Flex, Shear
      - Materials testing in progress – ECD 05/11
    - **Metallic Honeycomb:** Strip Rate, Visual Assessment, Substrate Temperature, Ultrasonic, Peel Resistance
      - Panel configuration and materials testing requirements being refined

Summary

- Laser technology has been proven and implemented as a result of this program
  - Handheld lasers implemented throughout the DoD
  - Robotic systems have been implmented at OO-AlC and OC-ALC
  - Full aircraft system is in development
- Implementation of laser coating removal technology has provided significant benefits to the USAF
  - Reduction of hazardous waste streams in de-painting operations
  - Reduction of risk to workers of exposure to hazardous paint strippers
  - Reduction of depot time for aircraft in de-painting operations

Contact Info

Environmental and Energy Quality Team	
Mr. Tom Naguy (AFRL/RXSC)	thomas.naguy@wpafb.af.mil (937) 656-5709
Mr. Randy Straw (*CTC*)	randall.straw@wpafb.af.mil (937) 255-5598
Concurrent Technologies Corporation	
Mr. Jim Arthur	arthurj@ctc.com (412) 992-5362
Mr. Jerry Mongelli	mongellg@ctc.com (937) 306-3310